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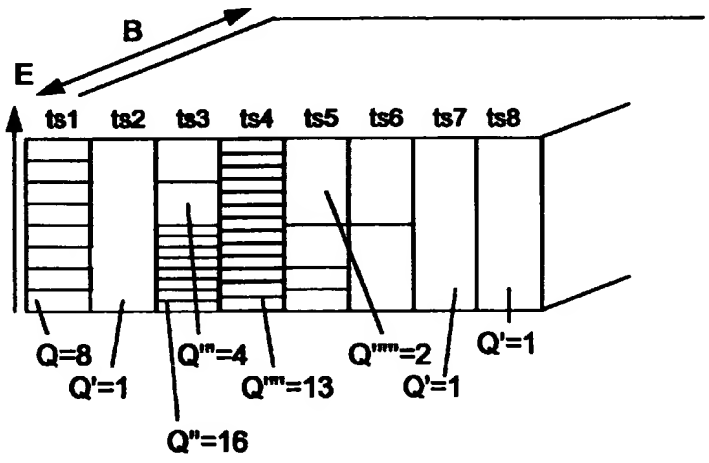
(54) Adaptive data rate TDMA/CDMA communications system

(57) Method and apparatus for adapting a rate of communicating data via digital user signals communicated on a communication link in a digital mobile communication system

The rate of communicating data via user signals communicated on a communication link between a transmitting and a receiving station in a TDMA/CDMA digital mobile communication system is adapted by selecting at least one spreading factor and a number of time slots according to the required rate of communicating data and the receiving capabilities concerning the TDMA/CDMA feature. An appropriate number of sequences of bits of the user signal is allocated to at least one time slot. The sequences are spread individually and arranged for a burstwise transmission of a transmit signal.

Fig.5



EP 0 876 008 A1

Description

Method and apparatus for adapting a rate of communicating data via digital user signals communicated on a communication link in a digital mobile communication system

Field of the invention

The present invention relates to a method and an apparatus for adapting a bit rate of a communication link in a digital mobile communication system.

Digital mobile communication systems comprise a plurality of base stations distributed in a way to cover the area of interest and to form a cellular network. The base stations are linked to a switching network which may connect the mobile communications system to a public switched telephone network (PSTN) or any other network. The base stations establish communication links to mobile stations which move freely inside the mobile communication system and will be handed over to an other base station in case they leave the present cell.

A radio interface with frequency channels for user signals transmitted from a transmitting station to a receiving station forms the communication link between a mobile station and a base station. The communication links in the communication system allow the exchange of any digital data and/or speech data.

In order to separate the user signals on the radio interface TDMA (time division multiple access), FDMA (frequency division multiple access) or CDMA (code division multiple access) techniques are used. The well known GSM (global system for mobile communications) system uses TDMA/FDMA and e.g. the IS-95 system uses CDMA/FDMA.

A future mobile communication system may use an other combination of the multiple access techniques. From T.Ojanperä, K.Rikkinen, H.Häkkinen, K.Pehkonen, A.Hottinen and J.Lilleberg, „Design of a 3rd generation multirate CDMA system with multiuser detection, MUD-CDMA", Proceedings of the 1996 IEEE 4th International Symposium on Spread Spectrum Techniques and Applications, Mainz, 1996, p.334-338, a proposal for a CDMA/FDMA system is known which introduces variable spreading gains to achieve variable bit rates of the communication links. This proposal does not fit with the GSM system infrastructure because soft handover and fast power control are required for the proposed system.

Objective of the invention

An objective of the present invention is therefore to identify a method and an apparatus for adapting a rate of communicating data via digital user signals of a communication link in a digital mobile communication system without requiring soft handover and fast power control. The objective is achieved by the method according to Patent Claim 1 and the apparatus according to Patent Claim 8.

Disclosure of the invention

According to the invention, a communication link between a transmitting and a receiving station for digital user signals is set up in a TDMA/CDMA digital mobile communication system. The digital user signals are separated from user signals communicated on other communication links by individual spreading codes and/or different time slots. In order to adapt a rate of communicating date on said communication link the method comprises the steps:

- selecting at least one spreading factor and a number M of time slots according to the required bit rate and the receiving capabilities, the spreading factor being representative of a number of chips of a spreading code and M being representative of a number of time slots of the communication link,
- forming at least one individual spreading code with chips in accordance with the selected at least one spreading factor,
- allocating sequences of bits of the user signal to the selected at least one time slot,
- spreading the sequences of bits individually in accordance with the spreading code,
- forming a transmit signal by combining the sequences allocated to the at least one time slot, and
- arranging for burstwise transmission of the transmit signal.

This fexible adaption of the bit rate facilitates the introduction of a future digital mobile communication system, like UMTS (Universal Mobile Telecommunication System) or FPLMTS (Future Public Land Mobile Telecommunications System).

Further advantageous characteristics are subject of the dependent claims.

The method according to the invention is advantageously developed in such a manner that, during a communication a request for a new bit rate is signaled, and the number of time slots M or the spreading factor Q of the communication link is updated for a receiving station with only TDMA capability or CDMA capability, respectively. For a receiving station with both TDMA and CDMA capability, the number M of time slots and/or the spreading factor Q can be updated. Based on the knowledge of the individual capabilities of the mobile stations an update of the radio interface parameters (M, Q) for any communication link is performed in order to achieve the new bit rate.

The receiving station can recognize the parameter change, but advantageously the number of the time slots M and/or the new spreading factor Q is signaled to

the receiving station.

The spreading factor is set to 1 in case a station with only TDMA capability is served. By doing so a TDMA/FDMA transmission is achieved. This facilitates a reduction in the amplitude variations of the transmitted signal.

In addition to allocating more time slots M or smaller spreading factors Q to a communication link, it is also possible to allocate two or more spreading codes to a user, so that the bit rate for this user is further increased. By combining all these methods a very flexible communication system is established which allows a gradual adaption of the bit rate according to the required service so that the resources of the radio interface are not wasted.

According to a further refinement of the invention, all chips are of equal duration. This allows a fixed clock frequency to be applied for spreading all the communicating signals so that transmission and reception of these signals is facilitated.

Brief Description of the Drawings

The invention will now be illustrated more detailed, with reference to a prefered but not limiting embodiment together with the enclosed drawings, wherein:

figure 1 represents a general view of a digital mobile communication system,

figure 2 describes a frame and burst structure of a TDMA/CDMA digital mobile communication system,

figure 3 describes a frame and burst structure with communication links of different bit rate,

figure 4a,b describes a burst structure with different bit rates,

figure 5 describes a frame and burst structure with different spreading factors, and

figure 6 represents a general view of a base station.

The digital mobile communication system according to Fig. 1 comprises a mobile switching center MSC in which an inter-working unit IWF is integrated in order to implement an interface to a public switched telephone network PSTN. A split of the digital mobile communication system into regional sectors is achieved by way of a plurality of mobile switching centers MSC each of which is associated with a regional sector, and which are networked to each other, within each regional sector, a mobile switching center MSC is linked to base stations BS via base station controllers BSC.

Each base station BS serves an individual cell. The digital mobile communication system has a cellular structure wherein hierarchical cells (macro, micro, pico cells) are served by one or different base stations BS. The links between the individual fixed components MSC, BSC, BS of the digital mobile communication system up to and including the base station BS are normally produced by lines. This structure of a digital mobile communication system is illustrative of a possible environment, in which a radio interface shortly to be described may be used. Another function split between different system components may also be chosen.

The structure of the digital mobile communication system shown in Fig. 1. serves to provide communication of a plurality of mobile stations MS. These mobile stations MS are linked to the base stations BS via a radio interface, thereby providing the mobile stations MS with a facility for mobile communication. The base station BS operate to provide radio communications within a radio coverage associated with a cell. However, as a rule the base station BS may provide radio coverage beyond the cell boundary area associated with an individual base station BS.

The radio interface between a particular base station BS and the three mobile stations MS according to Fig. 1 is typically distorted by a multipath propagation, which resultes in interferences between transmitted symbols and by interference from user signals of different communication links. The following will describe the radio interface of the downlink, the link from the base station BS to the mobile stations MS. The uplink is formed in a equivalent way and can employ the same transmitting scheme.

An operation and maintenance center OMC is connected to a base station controller BSC and fulfills operation and maintenance functions for the base station controller BSC and the base stations BS linked to this base station controller BSC. Information about faults and the traffic load of these components are provided to the operation and maintenance center OMC so that the operator will be warned. Whenever possible, the system adapts its configuration so as to provide continuous operation. The base station controller BSC performs radio processing functions, local call processing functions, local safeguarding and operation and maintenance functions. A major task is the management of the radio resources of the base stations BS. The base station controller BSC controls the base station BS to allocate the radio resources to the mobile stations MS and their user signals.

In Fig. 2, the frame and burst structure of the radio interface of a TDMA/CDMA communication system is shown. A TDMA user separation is established by a number of time slots ts. As an exemple 8 time slots form a frame. Each user signal is transmitted in one or more time slots ts. The bandwith B of the radio interface refers to a broadband frequency channel of e.g. 1,6 MHz for each time slot ts. An additional FDMA component may

be introduced allocating more than one frequency channel to a particular base station BS.

It is possible to allocate two or more user signals to a time slot ts by using a CDMA user separation. A number of user signals can be transmitted in a single time slot ts which are separated by different CDMA codes c (spreading codes).

A transmitted burst consists of two half bursts with data symbols d which are separated by a training sequence tseq1, tseq2,..,tseqK. The training sequences tseq1, tseq2,..,tseqK are specific for the K signals and are used for channel estimation. They are not necessarily required for the implementation of the invention. A guard period gp at the end of the burst prevents possible collisions between data symbols d of succesive bursts, as a result of different path lengths between mobile stations MS and base station BS caused by multi-path propagation with different signal delays.

The CDMA codes c consist of chips of constant length T_{chip} wherein Q chips spread one data symbol of duration T_{sym}. The CDMA codes c are also known on the receiver side so that despreading and user separation can be performed.

Referring to Fig. 3, an example of a state of the art allocation method for the radio resources is shown in order to ensure variable bit rates for different communication links according to a user specific need.

Time slot 1 and one CDMA code are assigned to user signals of user 1. Time slots ts1 to ts4 with one CDMA code and time slot ts6 with 8 CDMA codes are assigned to user signals of user 2 and 3 respectively. For user 4 a mixed assignment is chosen comprising time slot ts4 with 2 CDMA codes, time slot ts5 with 1 CDMA code and time slot ts8 with 4 CDMA codes. The more time slots ts and the more CDMA codes are assigned to a user, the higher the possible data communication rate (bit rate) for this user.

An alternative solution is a variation of the spreading factor Q according to Fig. 4a and 4b. A constant chip duration T_{chip} is assumed. The number of chips per data symbol d is adapted for a double bit rate compared to Fig. 2 by using a spreading factor of $Q'=Q/2$. If the spreading factor (number of chips per symbol) is fixed at $Q'=2Q$ the bit rate is halved. Since the burst duration and the chip duration T_{chip} are constant, the doubling or halving of the number of data symbols d per halfburst is equal to a variation of the bit rate.

Fig. 5 shows an example of the flexible bit rate adaption according to the invention. There are six different spreading factors from 1 to 16 in use in this example. The spreading factor Q, Q', Q'',Q''',Q'''',Q''''' is no longer constant for all the time slots ts1 to ts8 but adapted to supply the need of individual communication links. The spreading factor Q, Q', Q'',Q''',Q'''',Q''''' can be different for different time slots ts or can be different for the user signals within one of the time slot ts1 to ts8 of a frame or both. This method, i.e. the use of variable spreading factors Q, Q', Q'',Q''', Q'''', Q''''', can also be combined with the above-mentioned method of allocating different numbers of CDMA codes c and/or time slots ts to a user.

The flexibility of the digital mobile communication system is enhanced since even non CDMA mobile stations MS can be served by using a spreading factor Q'=1, see time slots ts2, ts7, ts8. A further degree of freedom is introduced in a TDMA/CDMA digital mobile communication system associated with communication at different bit rates in combination with adapting to a change in the radio propagation environments. An increase of the spreading factor Q corresponds to an increase of energy with which the information is transmitted. With an increase of energy it is possible to achieve a better interference suppression.

The above described method is implemented in a base station BS shown in Fig. 6. The base station BS comprises signalling means SM, control means SE, signal processing means SP and transmission means HF.

The signal processing means SP, e.g. a digital signal processor operates to receive user signals from different communication links from the network via the base station controller BSC for communication to the mobile stations MS. The user signals have to be transmitted to the mobile stations MS. Additionally, signalling information is received which is processed by the signalling means SM, e.g. in order to detect requests for new bit rates for the sender which is connected via the network. The signalling means SM also supply the receiving station with relevant information about the used spreading factor and/or number of time slots depending on the required bit rate.

Control means SE, e.g. a digital processor with a memory device operates to process actual information about the spreading factors Q,...,Q'''', the CDMA codes c, and the number M and position of time slots ts allocated to each communication link. The control means SE operates to receive updated information concerning these parameters from the signalling means SM and controls the signal processing means SP in order to form the appropriate burst structure.

Communication of signalling information from and to the mobile stations MS is effective to determine the required bit rate and the operating capabilities of these mobile stations MS with regard to the capability of these mobile stations MS to operate with TDMA/CDMA features. The individual capability of each mobile station MS is stored either in the base station BS or the base station controller BSC after this capability has been signaled. The control means SE operates to select a parameter set (Q, M) in accordance with the required bit rate and the transmitting and receiving operating capabilities of the mobile station MS. The control means SE, further operates to allocate sequences of bits of the user signals to M time slots ts and form the Q individual spreading codes c. A communication can use two or more spreading codes c in order to increase the bit rate of the transmission.

The signal processing means SP processes the parameters (Q, M, c) and the user signal to be transmitted and spreads the sequences of bits with the chips. The spread user signals are received by the transmission means HF which forms a transmit signal, by combining the different sequences. After digital/analog conversion, filtering and power amplifying the transmit signal is transmitted in a burstwise manner.

A receiver in the receiving mobile station MS comprises equivalent components so that the received signals can be converted to a base band representation, sampled, analog/ digital converted, despread and the bits of the sequences detected. Well known JD (Joint Detection) techniques can be employed. For the uplink, a corresponding transmission method may be employed.

Claims

1. Method for adapting a rate of communicating data via digital user signals communicated on a communication link between a transmitting (BS) and a receiving station (MS) which user signals are separated from signals communicated on other communication links by individual spreading codes (c) and/or different time slots (ts) in a TDMA/CDMA digital mobile communication system,
   comprising the steps of:

   - selecting at least one spreading factor (Q,.. Q'''') and a number M of time slots (ts) according to the required bit rate and the receiving capabilities, the spreading factor (Q,.. Q'''') being representative of a number of chips of a spreading code and M being representative of a number of time slots (ts) of the communication link,
   - forming at least one individual spreading code with Q,.. Q'''' chips in accordance with the selected at least one spreading factor (Q,.. Q''''),
   - allocating sequences of bits of the user signal to the selected at least one time slot (ts),
   - spreading the sequences of bits individually in accordance with the spreading code,
   - forming a transmit signal by combining the sequences allocated to the at least one time slot (ts), and
   - arranging for burstwise transmission of the transmit signal.

2. Method according to claim 1, comprising the step of signalling receiving capabilities concerning the TDMA/CDMA feature between the two stations (BS, MS) before selecting the at least one spreading factor (Q,.. Q'''') and the at least one time slot (ts).

3. Method according to claim 1 or 2, wherein

   during a communication a request for a new bit rate is signaled, and
   for a receiving station (MS) with only TDMA capability the number M of the time slots (ts) of the communication link are updated and for a receiving station (MS) with CDMA capability the spreading factors (Q, Q', Q'''') are updated.

4. Method according to claim 3, wherein

   the new number M of the time slots (ts) and/or the new spreading factor (Q,.. Q'''') are signaled to the receiving station (MS).

5. Method according to claim 3 or 4, wherein

   the spreading factor (Q,.. Q'''') for a station (MS) with only TDMA capability is set to 1.

6. Method according to one of the previous claims, wherein

   two or more spreading codes are allocated to a user, so that the rate of communicating data for that user is further increased.

7. Method according to one of the previous claims, wherein

   all the chips are of equal duration.

8. Apparatus (BS) in a TDMA/CDMA digital mobile communication system,
   with signalling means (SM) for

   - recognizing receiving capabilities concerning the TDMA/CDMA feature of a mobile station (MS),
     with control means (SE) for
   - adapting a rate of communicating data via digital user signals communicated on a communication link to the mobile station (MS) which are separated from other user signals by individual spreading codes and/or different time slots (ts)
   - selecting at least one spreading factor (Q,.. Q'''') and a number M of time slots (ts) according to the required rate of communicating data and the receiving capabilities,
   - forming at least one individual spreading code with Q,.. Q'''' chips, and
   - allocating sequences of bits of the user signal to at least one time slot (ts),
     with signal processing means (SP) for
   - spreading the sequences of bits individually,
   - forming a transmit signal by combining the sequences allocated to the time slot (ts),

with transmission means (HF) for

- arranging for burstwise transmission of the transmit signal.

9. Apparatus (BS) according to claim 8, wherein

the signalling means (SP) communicates information to the control means (SE) representative of a request for a new rate of communicating data, and wherein
the control means (SE) operates to update the number M of time slots (ts) of the communication link for a mobile station (MS) with only TDMA capability or update in addition the spreading factors ($Q_{,..}$ $Q^{''''}$) for a mobile station (MS) with CDMA capability.

10. Apparatus (BS) according to claim 8 or 9, wherein

the signalling means (SP) communicates information to the mobile station (MS) representative of a new number M of time slots (ts) and/or a new spreading factors ($Q_{,..}$ $Q^{''''}$) to be used for the communication link.

11. Apparatus (BS) according to one of the claims 8 to 10, wherein

the control means (SE) allocates the number M of time slots (ts) and the new spreading factors ($Q_{,..}$ $Q^{''''}$) for different communication links so that an overall rate of communicating data between the base station (BS) and the mobile stations (MS) is maximized.

12. Apparatus (BS) according to one of the claims 8 to 11, with signalling means (SM) for supplying the receiving station (MS) with relevant information about a spreading factor ($Q_{,..}$ $Q^{''''}$) and/or a number of time slots (ts) depending on the required bit rate.

Fig.1

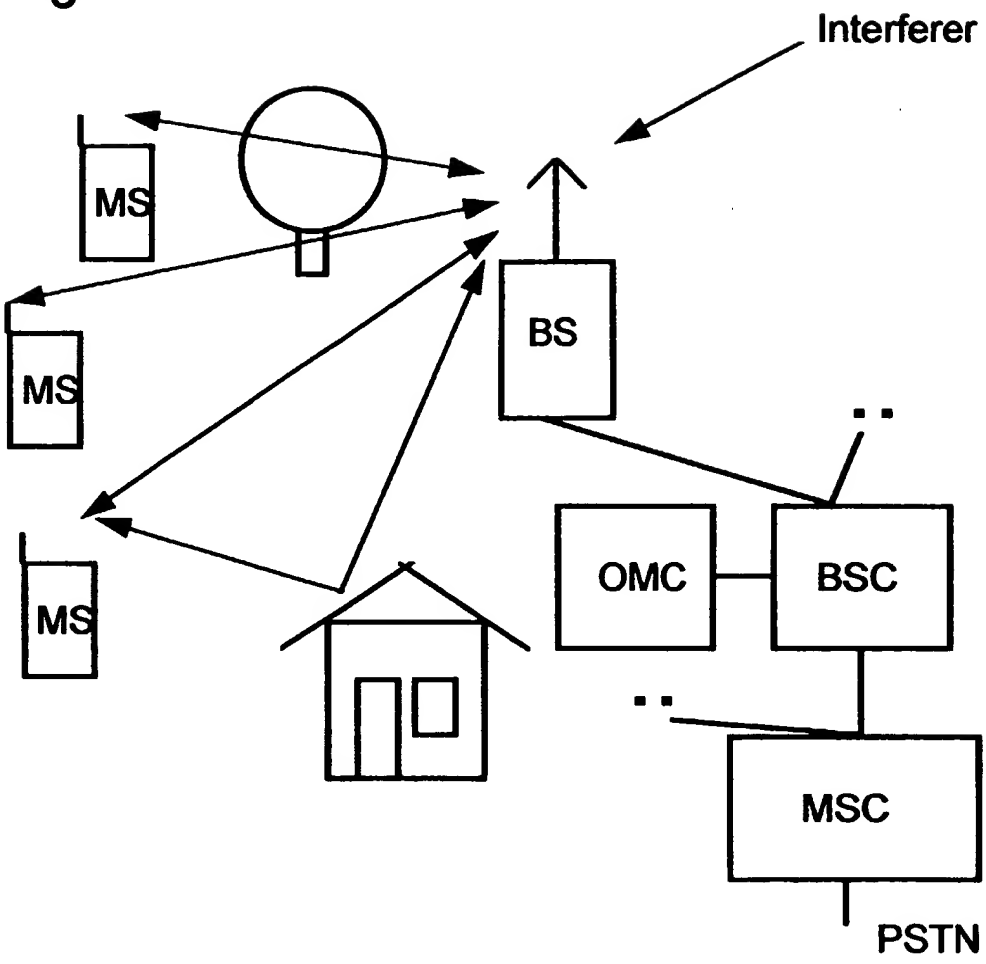


Fig.2

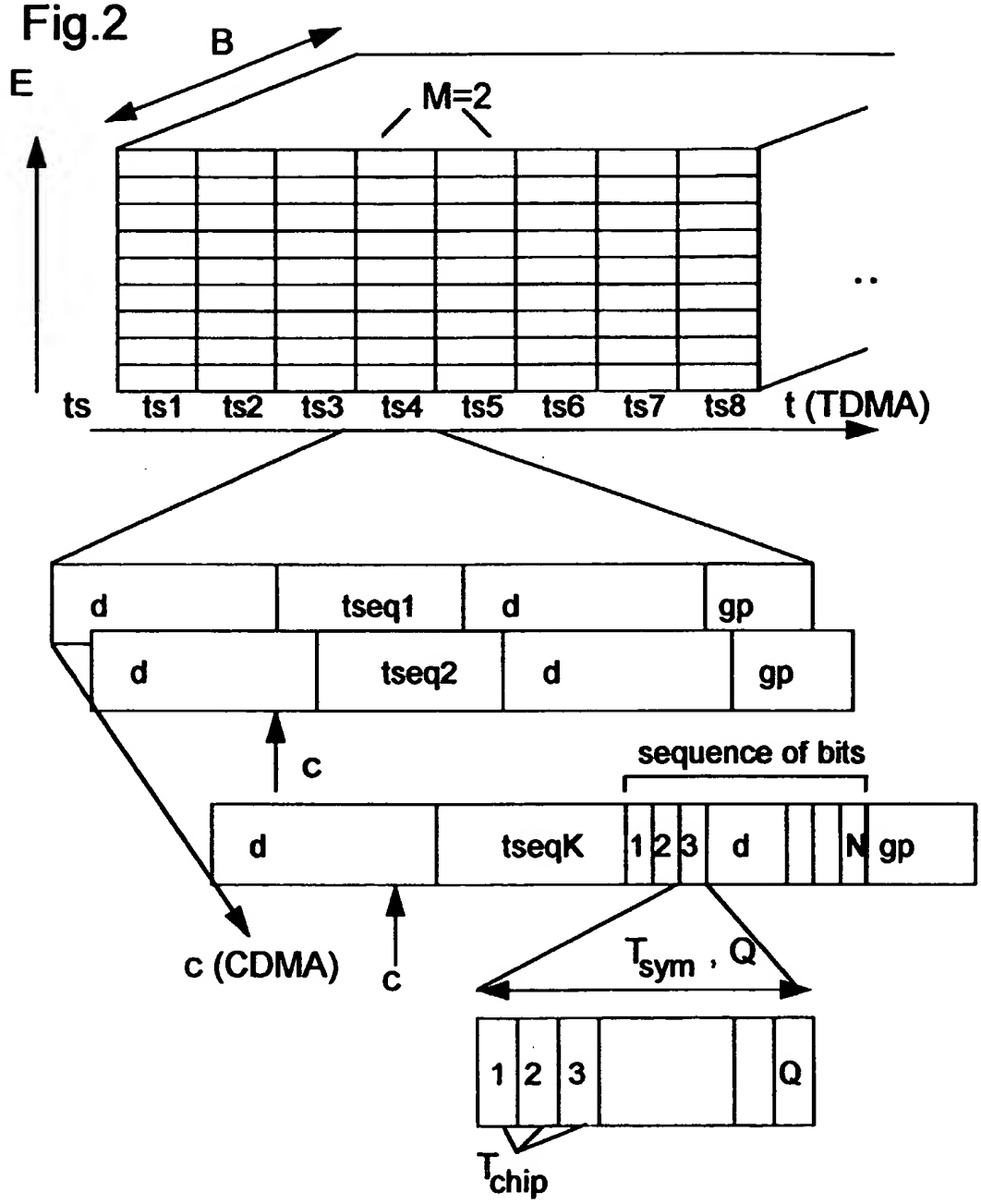
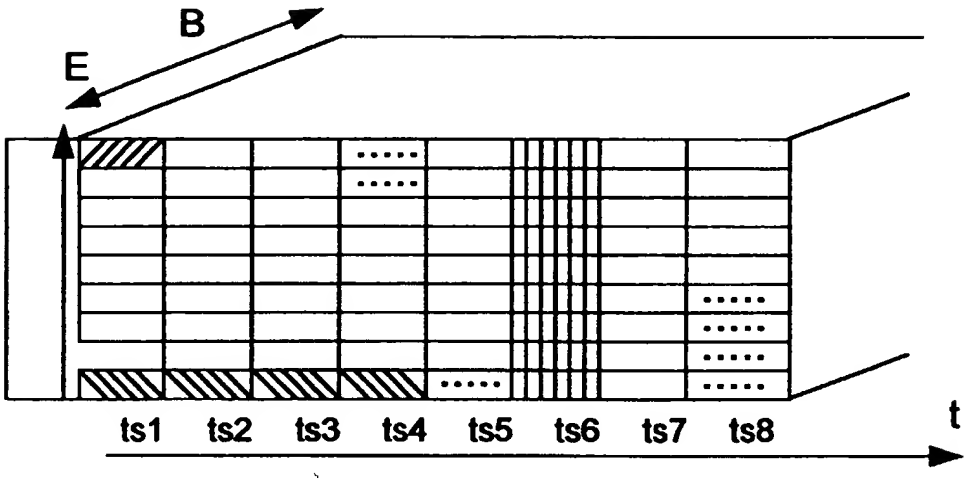

B
E
M=2
ts
ts1
ts2
ts3
ts4
ts5
ts6
ts7
ts8
t (TDMA)
d
tseq1
d
gp
d
tseq2
d
gp
c
sequence of bits
d
tseqK
1
2
3
d
N
gp
c (CDMA)
c
T_{sym} , Q
1
2
3
Q
T_{chip}

Fig.3



user 1 (1 x ts, 1 x CDMA code)

user 2 (4 x ts, 1 x CDMA code)

user 3 (1 x ts, 8 x CDMA codes)

user 4 (1 x ts, 2 x CDMA codes
1 x ts, 1 x CDMA code
1 x ts, 4 x CDMA codes)

Fig.4 a

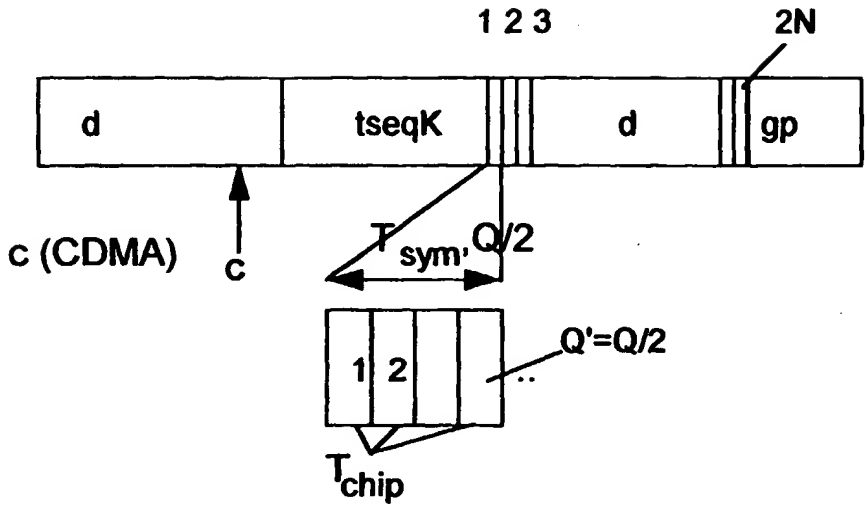

1 2 3
2N
d
tseqK
d
gp
c (CDMA)
c
T sym, Q/2
1
2
Q'=Q/2
T chip

Fig.4 b

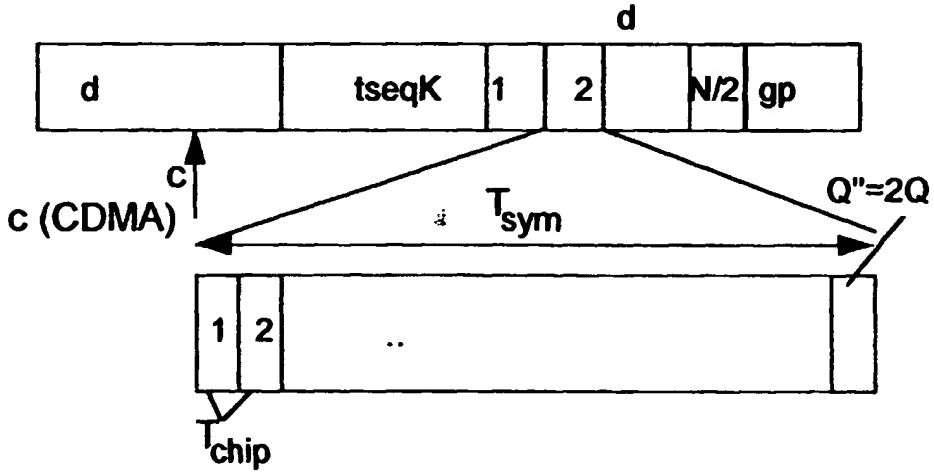

d
d
tseqK
1
2
N/2
gp
c
c (CDMA)
T sym
Q"=2Q
1
2
T chip

Fig.5

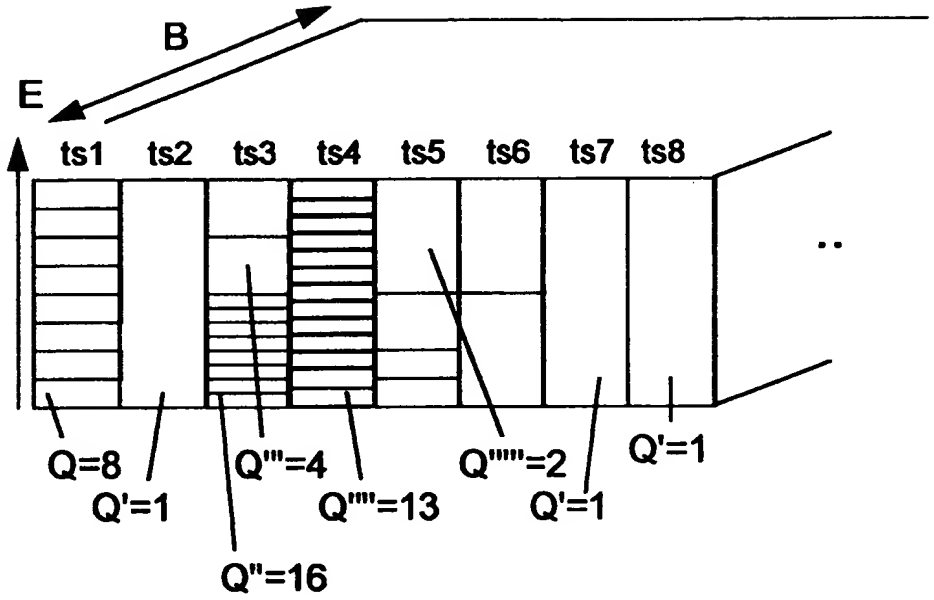
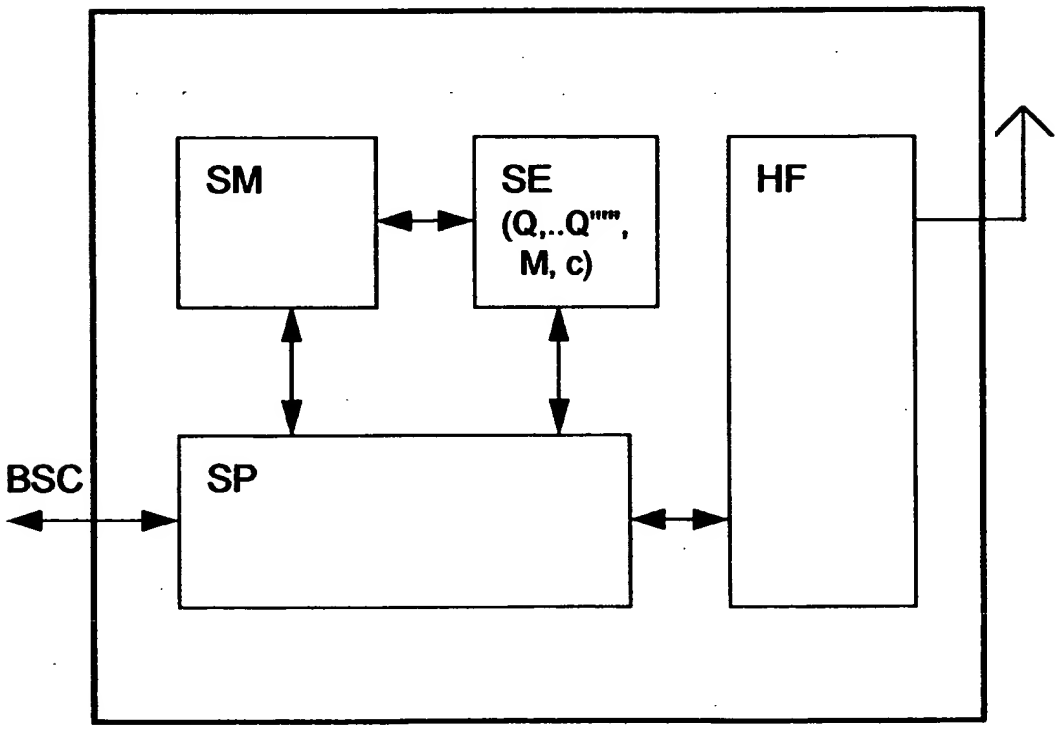

B
E
ts1
ts2
ts3
ts4
ts5
ts6
ts7
ts8
Q=8
Q'=1
Q"=16
Q'''=4
Q''''=13
Q'''''=2
Q'=1
Q'=1

Fig.6


SM
SE
(Q,..Q''''',
M, c)
HF
BSC
SP

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 40 0999

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	WO 93 15573 A (MILLICOM HOLDINGS UK LTD) 5 August 1993 * abstract * * page 2, line 20 - page 3, line 12 * * page 4, line 31 - page 5, line 36 *	1,8	H04B7/26
A	EP 0 658 991 A (NIPPON ELECTRIC CO) 21 June 1995 * abstract * * column 5, line 20 - column 6, line 24; figure 3 * * column 3, line 1 - line 20 *	1,8	
A	EP 0 571 745 A (ROKE MANOR RESEARCH) 1 December 1993 * abstract * * column 3, line 35 - column 4, line 43; figures 2-4 *	1,8	
A	WO 96 22639 A (QUALCOMM INC) 25 July 1996 * page 1, line 27 - page 2, line 8 * * page 2, line 37 - page 3, line 22; figure 1 * * page 6, line 21 - page 9, line 15; figure 2 *	1,8	TECHNICAL FIELDS SEARCHED (Int.Cl.6) H04B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	10 October 1997	Bossen, M

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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